Exploring Soud Waves

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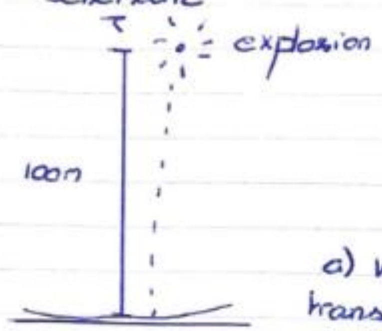
1. Introduction

Question 1

A fireworks rocket explodes at a height of 100 m above the ground. An observer on the ground directly under the explosion experiences an average sound intensity of 7.00×10^{-2} W/m^2 for 0.2 s. (a) What is the total amount of energy transferred away from the explosion by sound? (b) What is the sound intensity level (in decibels) heard by the observer?

Question 1

schematic



data

height = 100m above the ground

intensity = 7×10^{-2} w/m^2

Time = 0,2s

a) what is the total amount of energy transferred away from the explosion sound

b) what is the SIL level (dB) heard by the observe ?

calcules

a) $I = \frac{Power}{A} = \frac{Power}{4\pi r^2}$

energy = intensity × Area × time

energy = 7×10^{-2} w/m^2 × $4\pi(100m)^2$ × 0,2s

energy = $560\pi \approx 1759,3$ j

b) $SIL(dB) = 10 \log_{10} \frac{I}{I_0}$

$SIL(dB) = 10 \log_{10} \frac{560\pi \text{ j}}{10^{-2} \text{ w/m}^2}$

SIL (dB) = 152,45dB

2. Materials

→ Smart phone
→ Phyphox
→ Ruler with an uncertainty of (±0.5 cm)
→ MATLAB
→ Bluetooth Speaker

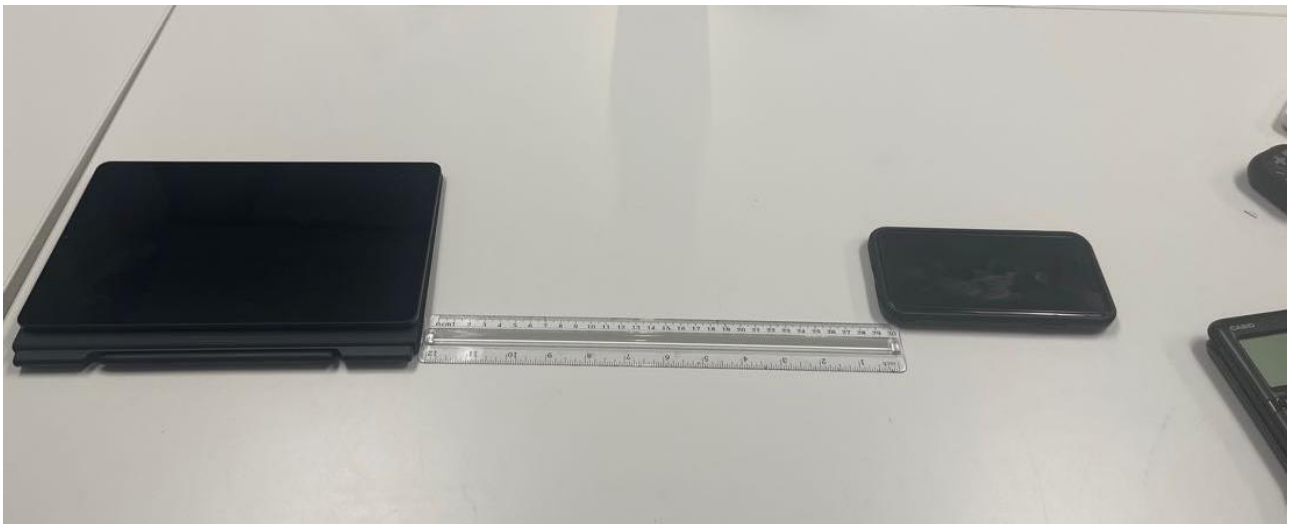


Figure 1(a) Photograph

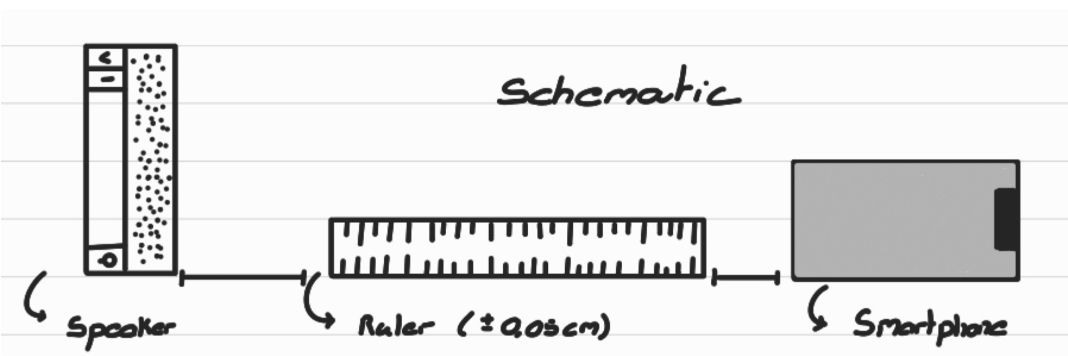


Figure 1 (b) schematic

3. Procedure

- **Perform calibration.**
  Sound Source: Bluetooth speaker
  Distance from phone to source: 1.39 m
  Set source to normal conversation level.
  Use 60 db as reference SPL
  Calibration offset: 113.51 db.

- **Measurement 1:**
  Sound Source: Bluetooth speaker
  Phone to source distance: $L_1 = 30 \pm 0.05$ cm.
  Environment: Parker study room
- **Measurement 2:**
  Sound Source: Bluetooth speaker
  Phone to source distance: $L_1 = 90 \pm 0.05$ cm.
  Environment: Parker study room
- **Measurements 3:**
  Sound Source: Bluetooth speaker
  Phone to source distance: $L_3 = 20 \pm 0.05$ cm.
  Environment: Parker study room

4. Results

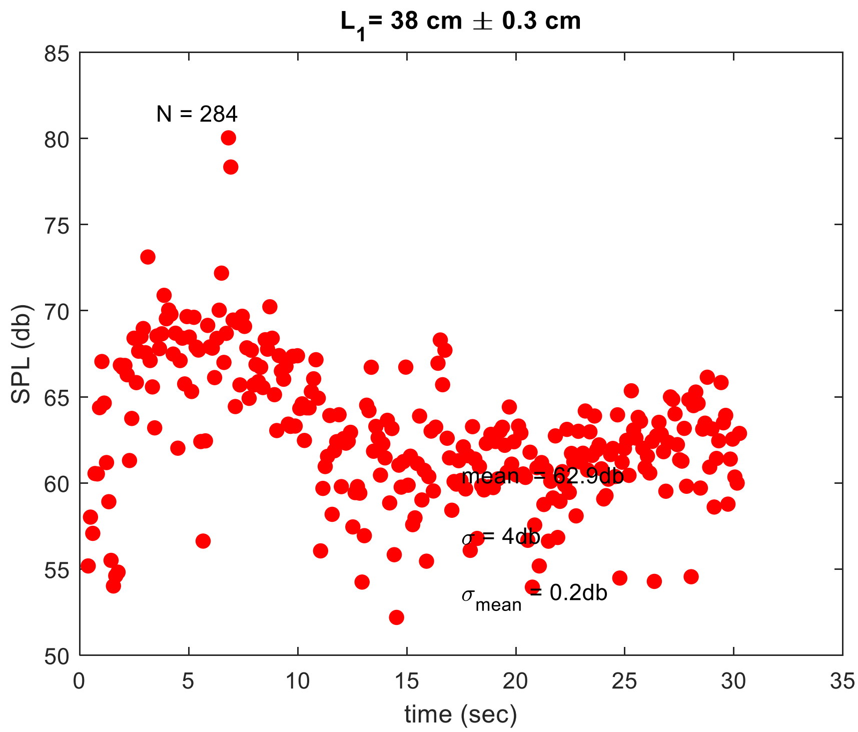


Figure 2: SPL versus time for measurement 1

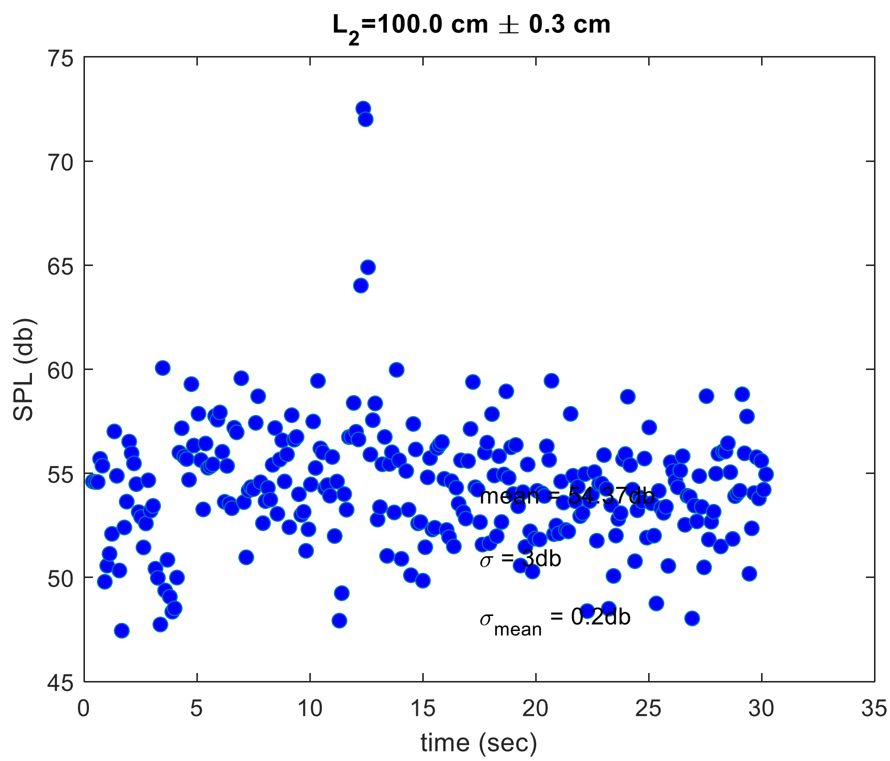


Figure 3: SPL versus time for measurement 2

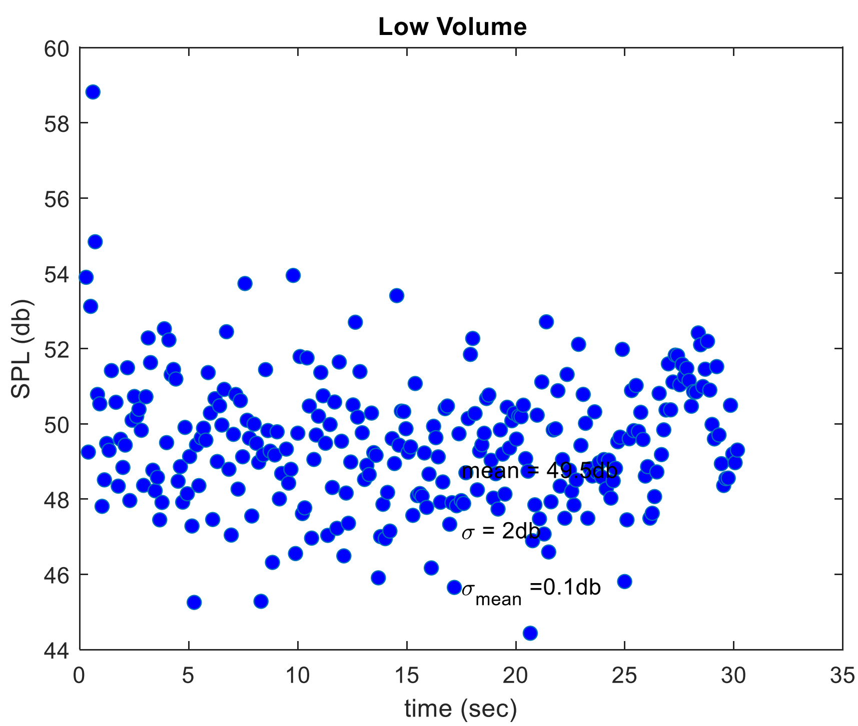


Figure 4: SPL versus time for measurements 3: low volume

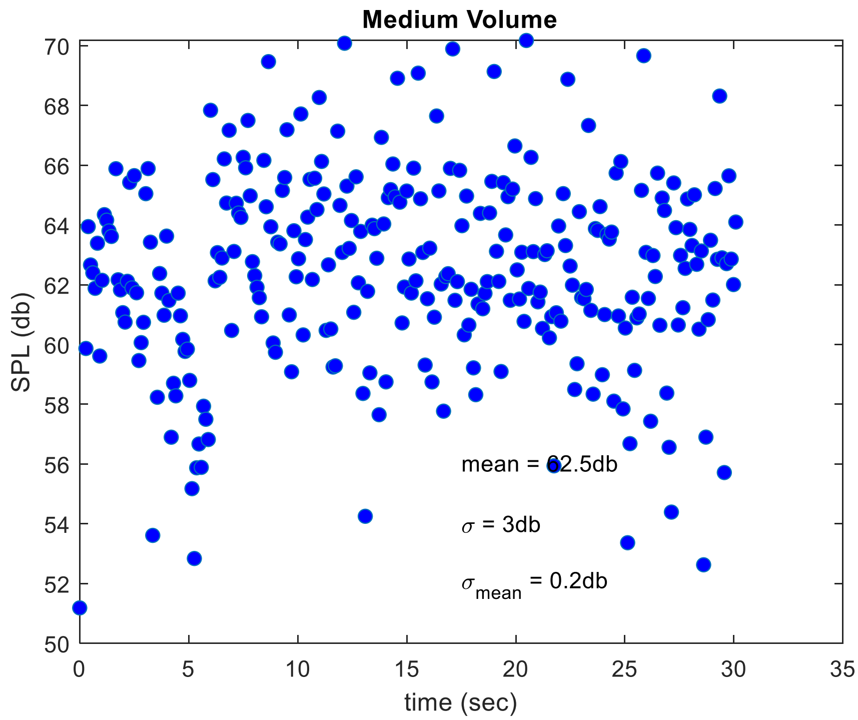


Figure 5: SPL versus time for measurements 3: medium volume

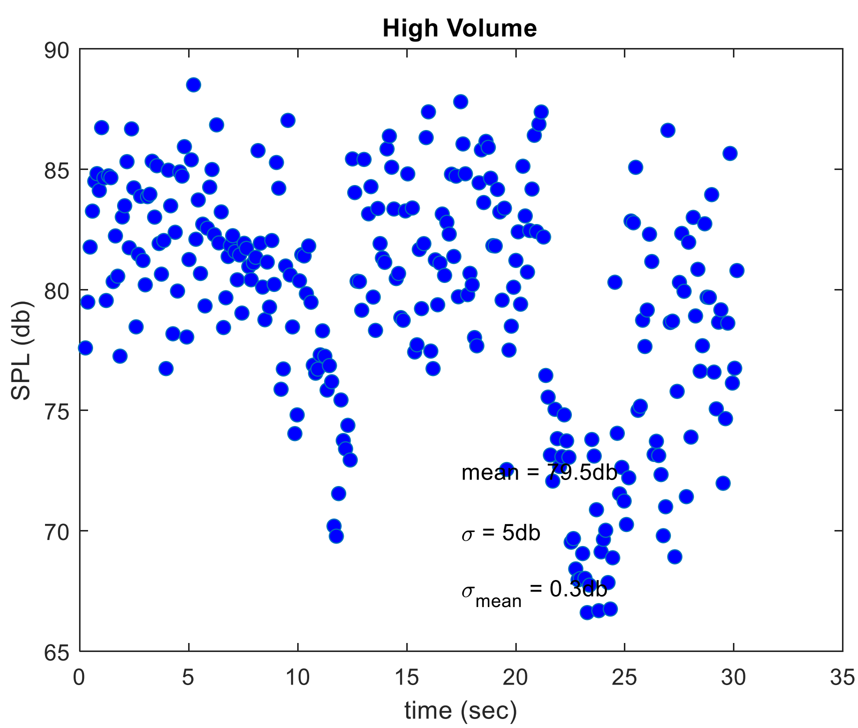


Figure 6: SPL versus time for measurements 3: high volume

- Fill in Table 2.

① $\bar{SPL} = 1/n \sum_{i=1}^{n} SPL = 62,9\,db$

② $\sigma_{SPL} = \sqrt{\frac{\Sigma = (SPL_i - \bar{SPL})}{n-1}} = 4\,db$

③ $\sigma_{\bar{SPL}} = \frac{\sigma}{\sqrt{n}} = 0,2\,db$

④ $P = P_0 10^{SPL/20}$
$= (2\times10^{-5}\,Pa)\,10^{62,9db/20}$
$= 0,0279$

⑤ $\sigma_P = \frac{P_0}{20} \ln 10 \; 10^{\bar{SPL}/20}$
$= \left(\frac{2\times10^{-5}}{20}\right)(\ln 20)\left(10^{\frac{62,9db}{20}}\right)(0,2)$
$= 0,84$

⑥ $I = \frac{P^2}{2\rho V} = \frac{(0,0279)^2}{2(1,2041\,kg/m^3)(343,21\,m/s)} = 9,42\times10^{-7}$

⑦ $\sigma_I = I\sqrt{(2/P)^2 \sigma_P^2}$
$= 9,42\times10^{-4}\sqrt{\left(\frac{2}{0,0279}\right)^2 (0,84)^2}$
$= 5,7\times10^{-5}$

⑧ Power $= I\, 4\pi L_i^2$
$= 9,42\times10^{-7}\cdot 4\pi\cdot(0,3)^2$
$= 1,07\times10^{-6}$

⑨ $\sigma_{power} = Power\sqrt{(1/I)^2(\sigma_I)^2 + (2/L_i)^2(\sigma_{L_i})^2}$
$= 1,07\times10^{-6}\sqrt{\left(\frac{1}{9,42\times10^{-7}}\right)^2(5,7\times10^{-5})^2 + (2/0,3)^2(1,07\times10^{-6})^2}$
$= 6,47\times10^{-5}$

- Sample calculations of each variable for Measurement 1

5. Discussions

Question 2

Do measurements 1 and 2 provide means to demonstrate the inverse square law as applied to sound waves? Justify your answer with some equations and words. No more than a page.

- ✓ Give the possible sources of errors for this experiment.
- ✓ Provide ways to improve the experience.

The experiment's goal is to look into the physical properties of sound waves. Our primary focus is on these waves, which are adaptable enough to move across several mediums but are most frequently recognised as mechanical waves moving through air, contributing to human aural experience. Sound waves alter the equilibrium positions of air components in the atmosphere as they travel, causing differences in density and pressure along their path. Sound intensity is quantified by measuring the sound pressure level (SPL) in decibels (dB). This measure is derived as 20 times the log10 of the difference between the standard sound pressure in air, which is fixed at 2 x 10-5 N/m2 (or 0.00002 Pa), and the sound pressure's root mean square (RMS). Nonetheless, human errors such as misplacing instruments such as rulers and variations in time could have an impact on the experiment. Despite these possible difficulties, the results provided a pretty accurate depiction of the observed occurrences.

Table 2: Give a descriptive caption here.

Measurements		$\overline{SPL}$ (db)	σ_{SPL} (db)	$\sigma_{\overline{SPL}}$ (db)	P (Pa)	σ_P (Pa)	I`` (W/m^2)	σ_I (W/m^2)	Power (W)	σ_{power} (W)
L_1 = 30 ± 0.05 (cm)		62.9	4	0.2	0.0279	0.84	9.42*10^-7	5.7*10^-5	1.07*10^-6	6.47*10^-5
L_2 = 90 ± 0.05 (cm)		54.37	3	0.2	0.0105	0.313	1.33*10^-7	7.93*10^-6	6.69*10^-8	3.98*10^-6
L_3 20 ± 0.05 (cm)	Low volume	49.5	2	0.1	5.97*10^-3	8.94	4.31*10^-8	1.29*10^-4	5.42*10^-9	1.62*10^-5
	Middle volume	62.5	2	0.2	0.0267	0.798	8.63*10^-7	5.16*10^-5	4.34*10^-7	2.59*10^-5
	High volume	79.5	5	0.3	0.185	8.48	4.31*10^-3	0.3951	4.88*10^-3	0.4474